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T1019 FUZE
AND
T48 GRENADE

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PROGRESS REPORT
JULY 1953 — SEPTEMBER 1954
REPORT NO. PR-54-92
PROJECT TA1-2708

DIAMOND ORDNANCE FUZE LABORATORIES
ORDNANCE CORPS • • • DEPARTMENT OF THE ARMY

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DIAMOND ORDNANCE FUZE LABORATORIES

DOFL PROJECT 32.2-6944

WASHINGTON 25, D.C.

DOFL REPORT PR-54-92

25 October 1954

PROGRESS REPORT

on

FUZE, GRENADE, HAND, T1019

and

GRENADE, HAND, FRAGMENTATION, T48

(Ordnance Branch No. TA1-2708)

July 1953 ..... September 1954

ORDNANCE CORPS • • • DEPARTMENT OF THE ARMY

FOREWORD

The Electromechanical Laboratory, Diamond Ordnance Fuze Laboratories, is developing an impact fuze, T1019, in conjunction with the development of Grenade, Hand, Fragmentation, T48. The proposed fuze consists essentially of a mechanism, triggered by target impact, which rebounds the grenade from the point of contact, producing airburst of the main fragmentation charge through a delay element. The grenade can be either hand- or rifle-projected. The airburst initiation should result in increased casualties over similar rounds fuzed for fixed-time or impact initiation.

FOR THE COMMANDING OFFICER:

W. S. HINMAN, Jr.
Technical Director
Diamond Ordnance Fuze Laboratories

1. GENERAL DESCRIPTION

The Electromechanical Laboratory, Diamond Ordnance Fuze Laboratories, is developing the airburst anti-personnel grenade and fuze; Grenade, Hand, Fragmentation, T48; with Fuze, Grenade, Hand, T1019. The T1019 is a mechanical fuze intended for this combination hand-rifle grenade and employs a rebounding type mechanism to produce airburst of the main charge (after impact) at a sufficient height to result in optimum number of casualties to personnel.

Some characteristics specified for the fuze in letter from OCO dated 9 October 1952 are:

a. Should be detonator safe.

b. Should have delayed arming (0.85 ± 0.15 sec).

c. Should function as a result of impact equivalent to a 6-in. free drop on concrete.

d. Should function airburst (after impact) at a sufficient height to give adequate effect against personnel.

e. Should be waterproof.

f. Should have a 10-year minimum shelf life, and preferably 20 years.

g. Should have a low-unit cost and be mass producible.

h. Should meet temperature requirements set forth in the Department of Army Special Regulations 705-70-5, dated 26 December 1950, including change No. 1 dated 2 February 1951.

i. Should pass the tests for use in the development of fuzes described by the Department of Defense Military Standards Mil-Std 300, 301, 302, 303, and 304, all dated 6 July 1951.

j. Should be air transportable in all phases of operation and be safe to handle and serviceable for subsequent use after air drop in standard air-drop containers.

2. STATUS

Work on the project was requested formally by an OCO letter dated 9 October 1952, and the following nomenclature assigned to this development program: Grenade, Hand, Fragmentation, T48; with Fuze, Grenade, Hand, T1019.

Initial work consisted of making simplified grenade mock-up models to investigate the rebound action. It was considered that the smallest, lightest source of energy required for the rebound was a gas-producing blank cartridge. Several types were tried, including shotgun cartridges and caliber .32 and .38 S&W blank pistol cartridges, with the conclusion that the .32 blank was physically small enough for a practical fuze and had sufficient energy if applied efficiently.

Since it was found that stabilization in flight was necessary to give the orientation required for proper rebound function upon impact, work was undertaken to develop a stabilizer which would be effective during the low-velocity flight of hand throws. Of numerous types tested, only the cloth-insheathed coil spring provided effective stabilization with light weight and compactness.

With indications that satisfactory stabilization had been obtained, further effort was directed toward producing a simple, reliable, inexpensive fuze design and grenade packaging, which could be fabricated by contractors in test quantities for engineering evaluation.

Several separate preliminary design types have been investigated for the T1019/T48. Basic components included in all types are: (1) a simple mechanical timer which arms the fuze; (2) a striker, either spring-loaded or graze type, to initiate upon impact; (3) a blank cartridge; (4) a detonator-safety system, including a short pyrotechnic delay for rebound-airburst detonation; (5) a rifle-launcher adapter tube affixed to the base of the grenade; and (6) a cloth-insheathed spring stabilizer.

The current models have the following functioning cycle: (1) delayed arming until 0.85 ± 0.15 sec after projection; (2) direct-impact functioning after arming.

This report pertains to progress on the T1019/T48 design initiated by DOFL in May 1953, which has received the majority of project effort. For information on preliminary types, refer to NBS Report No. 4A-164, June 1953.

Efforts on the T1019/T48 project have been given reduced priority in favor of work on the T1018 and the T1012 fuzes, and other projects as directed by OCO.

3. CURRENT PROGRESS

3.1 T48 Grenade

The present T48 fragmentation member is basically the M26 grenade body, with the addition of a rifle-launcher adapter tube and cavity liner accepting the T1019 fuze. This added tube results in a "potato masher" appearance of the T48.

The lightweight aluminum alloy adapter tube accepts the standard M7A3 rifle-grenade launcher. Assembly to the fragmentation member is completed after HE loading, by crimping the thin metal-attaching piece, as shown in figure 1. Models have been proof-tested by repeated launching using both the M3 grenade and M7 auxiliary cartridges without failure; and by the additional test of placing the adapter tube one-half way on the grenade launcher, such that the ignited auxiliary cartridge impacted against the closing disc. Adapters have been made from bar stock in a design applicable to impact extrusion, and also from seamless tubing closed by a disc shouldered internally and upset.

Cavity liners of thin-drawn gilding metal, including a section of ASA intermediate electric-socket, rolled thread to accept the T1019 fuze, have been purchased from commercial sources. The T1019 fuze requires a larger liner and thread diameters than specified for the M26 grenade fuze holder (Dept. Army Pc Mk No. 82-1-109). The intermediate electric-socket, rolled thread was chosen because of ready formability in thin-metal sections.

To date, all hand-throw trials conducted on the 16-in. (extended length) nylon-insheathed spring stabilizer have indicated satisfactory stabilization. The stabilizer is a helix of 0.035-in. steel wire wound 1-1/2 coils/inch, covered by shear nylon yard goods, plain weave 100 threads/inch, 0.8 oz/square yard. To lend adequate rigidity, the spring is under slight compression when the stabilizer is extended. The assembly is very light (1/2 oz).

Previous design featured the stabilizer compressed around the launcher adapter previous to use, inclosed in a thin, tubular aluminum cover. This is being revised to place the stabilizer inside the adapter tube, which is then capped at the end. Throw tests have indicated that a stabilizer of this reduced diameter affords sufficient stability. It has advantages over the previous design in that it affords simpler, more rugged external construction, is easier to seal, and is of reduced weight.

The stabilizer is removed for rifle projection. Launch tests have shown that the light, aluminum-alloy adapter tube alone provides sufficient stabilization at rifle-launch velocities.

The safety handle, a thin aluminum stamping, locks the T1019 fuze and constrains the stabilizer cover cap.

Considering probable conditions of tactical application, one operation to ready the grenade appears the maximum allowable: (1) For hand projection, the setback ring is stripped off manually. The thrower's grip retains the safety handle until release. (2) For rifle projection, the

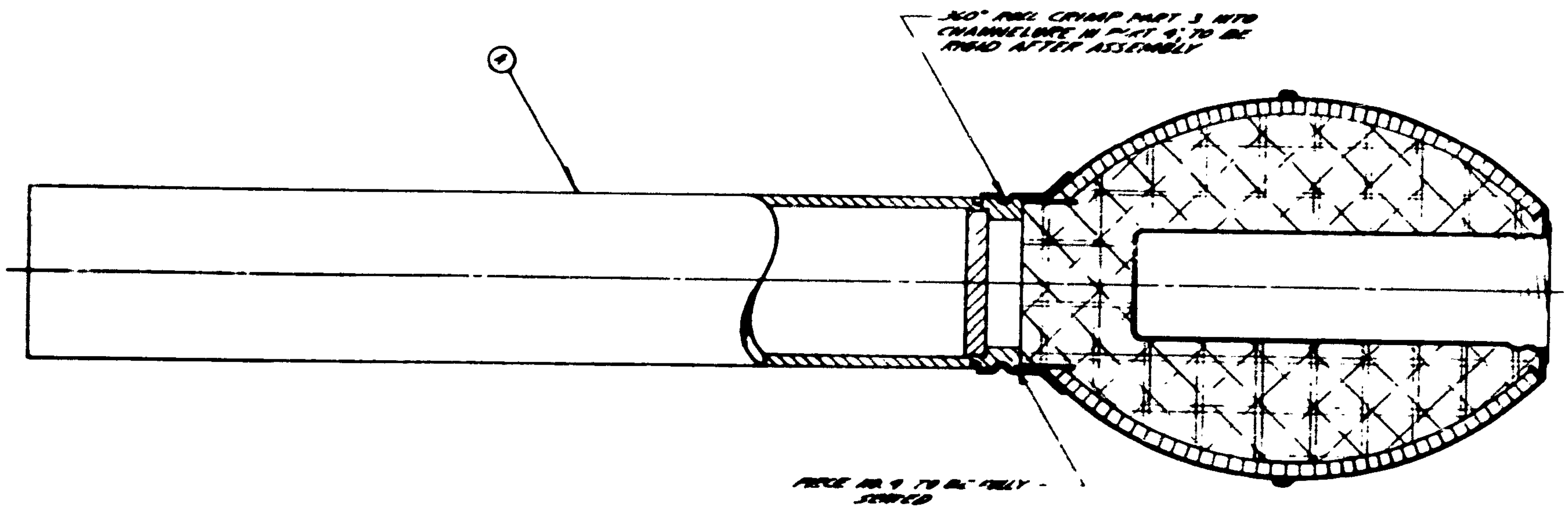

Figure 1. T48 Grenade body.

cover cap and stabilizer are pulled off sharply to the rear. This clears the adapter tube for placement on the rifle grenade launcher. The setback ring retains the safety handle until it is removed rearward by projection acceleration.

A one-piece, clip-fastened, sheet-metal setback ring with integral pull tab is proposed for the inclosed stabilizer assembly. For removal as in (1) mentioned in previous paragraph, the tab is pulled sharply, breaking the bent clip.

The previous external stabilizer, hard-rubber setback ring, and safety handle are shown in figure 2 (a and b).

3.2 T1019 Fuze

The T1019 fuze is comprised of a flanged tubular cup which is the fuze body, to which are assembled the components for arming, firing the cartridge, and detonator safety. The cartridge blast is retained in this cup. All fuze parts not required for further explosive-train functioning (arming timer, nose cap, cartridge sleeve) are ejected for rebound in a manner similar to a single-shot firearm. Powder flash initiates the delay detonator through a vent. The fuze is an externally assembled unit screwed into the nose of the grenade.

The original layout design is shown in figure 3.

Subsequent handling of test models indicated that major groups of components should be combined into several externally completed subassemblies, to facilitate final assembly and simplify the fuze.

3.2.1 Arming-Firing Subassembly

The rebound cartridge is contained in the bottom of the main axial well of the blast cup. Above this, capping the open end of the well, is the arming mechanism which initiates the cartridge on impact.

Models of a 3/4-sec mechanical timer, which afforded reliable arming function, were constructed. This timer comprised a drive spring, several small gears, and a runaway escapement; it replaced the simplified NBS simulator (drive spring only), a few models of which were used in initial tests. The timer is locked by a spring-loaded pin until release of the safety handle. During arming, the timer shaft rotates 3/4 turn, after which the cartridge sleeve is freed for forward motion, and the rotor arms (section 3.2.5). Impact moves the sleeve forward, initiating the cartridge.

In the first assemblies, the timer shaft was keyed to the separate striker holder, following the original layout (figure 3). This method produced assembly difficulty and some rotational inaccuracy. An integral timer shaft and striker holder appeared requisite. To further simplify the mechanism, striker and cartridge sleeves were combined into a single piece, and a rimless cartridge used. The resulting modification is shown in figure 4.

The modified timer is assembled, wound, and locked separately from the fuze, then inserted with the blank cartridge during final loading. High-explosive components are then loaded in order of their increasing output (section 3.2.5).

As a result of attempts to simplify the arming-firing subassembly, an elementary timer was conceived and tested in mock-up form in February 1954. This timer has a single central gear, an escape wheel and pinion, and a large diameter, massive verge. The spacing is such that the verge is concentric with the central gear and oscillates in free-axle fashion on the rotating main shaft. The advantages of this design are that it has only a single pinion position, and eliminates assorted components and fabrication operations required for prior timer designs.

A pilot model timer of proper configuration for the fuze was constructed. This timer, designated REL 1040 (figure 4) yielded 3/4 sec with 9 to 6-in.-oz torque output, a quite adequate value. Longer arming time, as one sec, may be obtained by reducing torque.

The timer was further redesigned at DOFL for application to rapid production techniques: The body is a drawn-aluminum shell; the single insert plate is punched from aluminum sheet; and the shaft is a turned, round piece to which is fastened a punched bridge of thin, steel sheet acting as spring mount, stop, and stud to block the slider sleeve. The previous spring-loaded, inertia-released striker was simplified to a direct, graze-type point on the timer shaft.

Models are under construction at DOFL for testing T1019 assemblies.

3.2.2 Nose Cap

The source of energy for rebounding the T48 from point of impact is a modified caliber .32 S&W blank cartridge. Several types of propellant powder have been tested to determine suitability for use in this unique ballistic application. Exploratory rebound trials against various characteristic target materials have been conducted.

At the expense of greater fuze size and structural requirements, preliminary experimental models effected rebound by ejecting greater mass by the use of larger, more powerful cartridges (section 2).

Figure 2a. Cutaway T48 and T1019 subassembly revision.

Figure 2b. T48 Grenade with external stabilizer.

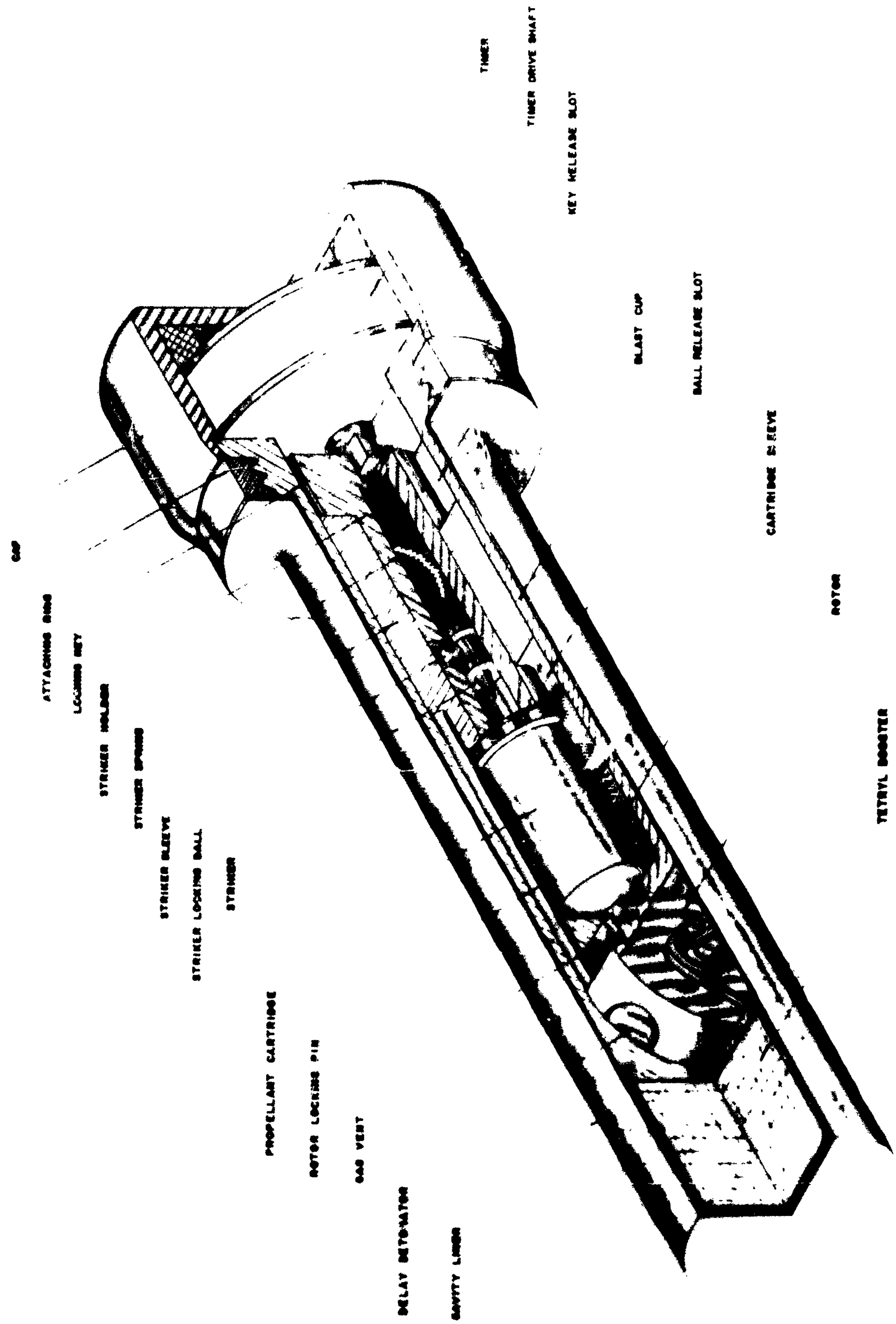

Figure 3. T1019 Fuze, first design.

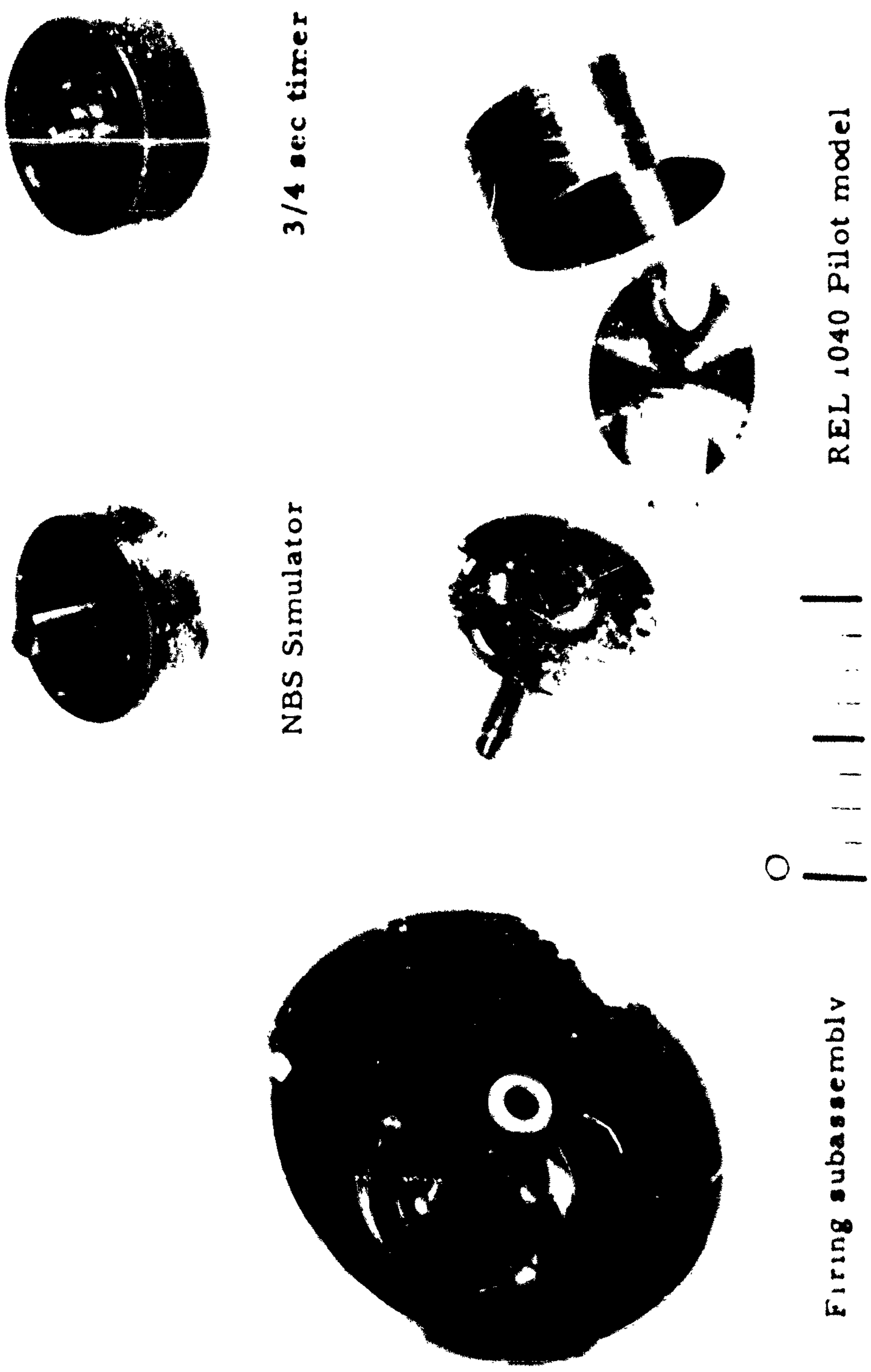

Figure 4. Timer models

The figure 3 assembly used a covering nose cap of relatively small frontal area (0.8 sq in). Rebounds observed from impact on soft earth were found to be unsatisfactory. An impact against concrete resulted in a vertical rebound of over 20 ft, and later tests made against several hard target materials have exceeded this figure. This disparity in rebound heights from rigid targets and from soft, energy-dissipating targets indicated the necessity of backing ejected parts.

In view of grenade weight and size limitations, it was decided to substitute a nose cap having a larger presented area in preference to increasing the ejected mass. This additional area would better restrain motion of the ejected parts, thereby increasing rebound reaction without appreciably increasing grenade weight.

Pilot nose caps having a wide flange at the base, conforming to the M26 grenade body, were spun from 1/16-in. copper sheet. This cap was a compromise between the desired optimum air foil and effective flat frontal area. A small number of hand-throw trials, with smoke indicators for showing the occurrence of detonation, were conducted with this cap against soft, sandy loam, in order to get a comparison with previous trial results in which the 1-in. diameter cap was used. Good rebounds were obviated when the spun copper ruptured; this material was employed because of its ready formability into laboratory test samples. The tests indicated that this cap shape did not present enough frontal area immediately upon contact; however, the larger area gave increased performance.

Using the information gained from the temporary copper models, an open-cup nose cap was designed of pressed 0.059-in. sheet steel. This cap was again a compromise, the angled sides presenting a larger immediate contact surface than the flanged design of the copper caps, yet maintaining low bulk and aerodynamic drag. The open end fits over the M26 grenade body when the fuze is inserted, as shown in figure 2a.

The punched sheet-steel hinge (for the safety handle) is spot welded to the top of the cap. The timer shell and nose cap are riveted together, forming the frame for the arming-firing subassembly (section 3.2.1).

The three cap types are shown in figure 5.

3.2.3 Rebound Tests

In late 1953 a more extensive series of rebound tests, to study the effect of various parameters on rebound performance, and to determine a configuration which would yield effective practical performance, was initiated. Major variables included target material mass, presented area, and shape of ejected parts, propellant powders of different burning rates and impact velocity. The tests have been conducted on an operational basis, by impacting grenades containing firing mechanisms and cartridges against targets. Due to the large number of indeterminates in this unique ballistic application, such as system efficiency, exact resistance afforded by earth targets, etc., rigorous mathematical analysis was considered impracticable. Approximately 175 trials have been conducted to date.

A portable boom framework with mechanical drop release was constructed for impacts comparable to hand throw. This afforded remote release for operator safety, and accurate drop height. The small impact area permitted close control of both target consistency and photographic coverage. Rifle launches were made from an M1 rifle in a fixture mount.

Initial check trials confirmed that the amount of ejected mass (without area increase) to secure sufficient rebound from earth was prohibitively large. A slug doubling the ejected mass produced little effect.

Hard, rigid targets of maximum backing produced very high rebounds with no nose cap being required. Vertical rebounds of 40 ft from hard asphalt, 60 ft from concrete, and even higher from steel plate have been recorded. These represent maximum values for the system, the impact surface approaching a theoretical infinitely rigid backing, and all available energy of the .32-blank cartridge imparted to the grenade. Fast-burning powders gave the highest rebounds from non-deforming surfaces.

A value of 40 ft was estimated as the practical maximum to be expected in field use, applying to rocky or deep-frozen ground, or similar surfaces. As will be shown later in this text, such an extreme value of free, unimpeded rebound is offset by actual detonator delay, so that the airburst occurs within effective height limits.

Impact materials in the medium-hard category yielded highest and most consistent performance when a nose cap was employed, although in many instances rebound was quite sufficient without a cap. With a cap of the tapered type attached, rebounds averaged in the 15- to 25-ft range from materials such as packed earth, settled wet sand, earth containing small gravel, and planking.

Hand-launch impact tests against hard and medium-hard target materials were discontinued after trial No. 25, except for isolated comparison tests. Results indicated that little difficulty would be encountered in achieving a rebound of sufficient magnitude.

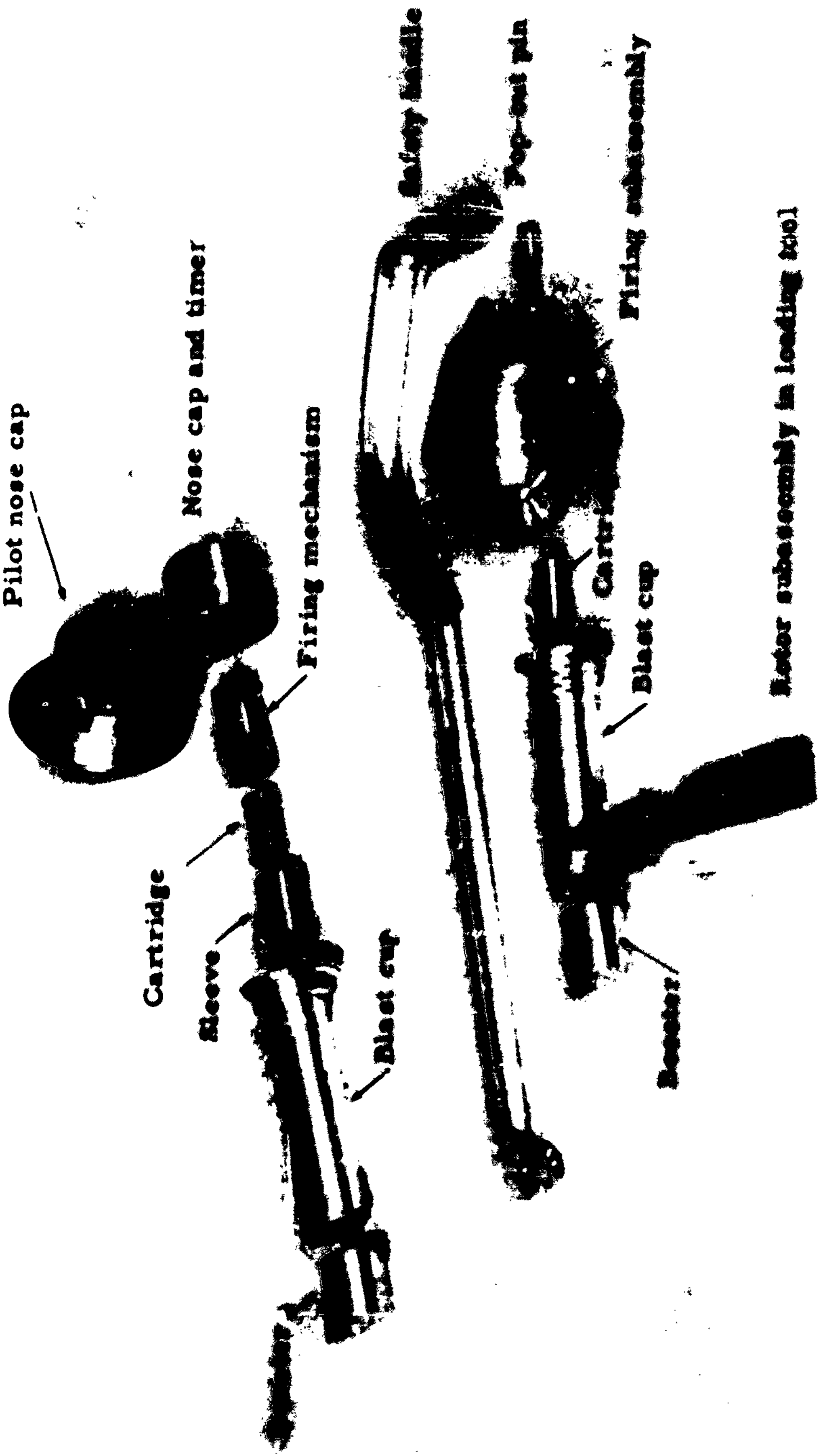

Figure 5. T1019 Fuze models, first design and subassembly revisions (disassembled).

Subsequent effort was directed toward securing and improving rebound from soft materials such as spaded or plowed earth, loose sand, or mud, and average targets such as clay-loam or sod. It is this group which produces the greatest difficulty, especially on rifle projection, offering little constraint to the motion of ejected parts, and dissipating cartridge energy without producing efficient rebound. Also, this group of relatively soft targets is expected during tactical usage.

Fair rebounds from soft targets were obtained with a flat nose disc and fast-burning cartridge powder (as Dupont Pistol No. 6). However, the disc gave poor aerodynamic shape, reducing rifle-launch flight time by several seconds, and added bulk. Also, it appeared very likely to cause damage to the fuze during jolt and jumble.

In the spring of 1954, a spring-loaded, inertia-released striker device which fired the cartridge only after impact deceleration had dropped to a low value, as 10g, was tested. Marked increase in rebound from soft targets was immediately noted. These results showed that the sensitive fuze had been firing the cartridge on contact when the grenade still had considerable forward velocity into the soft target material, and a major portion of cartridge energy was being used up in overcoming forward momentum. The device delayed firing until grenade velocity was reduced by the impact material.

A pyrotechnic delay in the cartridge, between stab primer and propellant powder, was considered a more practical way of achieving short delay. Less effective, being based on average deceleration time for all impacts, this simple delay unit would be far less expensive than the assembly of machined components. Rough computations and subsequent tests indicated that an 8-millisec delay should give satisfactory performance. Tests are still in progress.

The present T1019 fuze assembly incorporates a delay cartridge initiated by a graze point on the timer shaft (section 3.2.1), and the tapered nose cap.

The method works quite well with this light, low-velocity missile. It does not seem feasible to apply the delayed rebound system to heavier, higher-velocity rounds, due to the extreme burial in earth targets.

3.2.4 Relationship Between Height of Rebound and Height at Detonation

The difference between rebound height and detonation height is quite distinct. Rebound height is that maximum distance above the target to which the grenade would rebound if unimpeded, i.e., free rebound height. Detonation height is that actual distance above the target, along the rebound trajectory, at which the grenade detonates as a result of the delay of the detonator. The relationship may be expressed as follows:

The height, H_B, of the grenade at any time t seconds after the initiation of rebound is:

$$H_B = v_o t - \frac{gt^2}{2} \quad \text{feet above target} \qquad (1)$$

where v_o = initial upward velocity

t = time elapsed since initiation of rebound

g = acceleration of gravity

The height at which actual detonation of the grenade will occur, H_d, is determined by v_o, g, and the (time) delay of the detonator, t_d.

$$H_d = v_o t_d - \frac{g t_d^2}{2} \quad \text{[from equation (1)]}$$

$$\text{or, } H_d = t_d \sqrt{2gH_{B\ max}} - \frac{g t_d^2}{2} \qquad (2)$$

where t_d = (time) delay of detonator

As an example, let t = 0.2 second; then,

$$H_d = 1.6 \sqrt{H_{B\ max}} - 0.64 \text{ ft}$$

The free-rebound height, $H_{B\ max}$, may vary from 1 ft to 60 ft due to different target materials, but actual detonation height, H_d, for a 0.2-sec detonator delay will vary within the height limits of 1 ft to 11-1/2 ft.

A useful relationship is:

$$H_d = 8t\sqrt{H_{B\ max}} - 16.1\ t^2 \text{ ft} \qquad (3)$$

Graphs of figure 6 follow this relation. The curves plotted for 0.2-sec and 0.3-sec delays illustrate the reason for choice of 0.25 sec as the interval between rebound initiation and grenade airburst. It may be pointed out that a shorter delay would limit detonation height for free rebounds in the 6-ft region, as from average earth

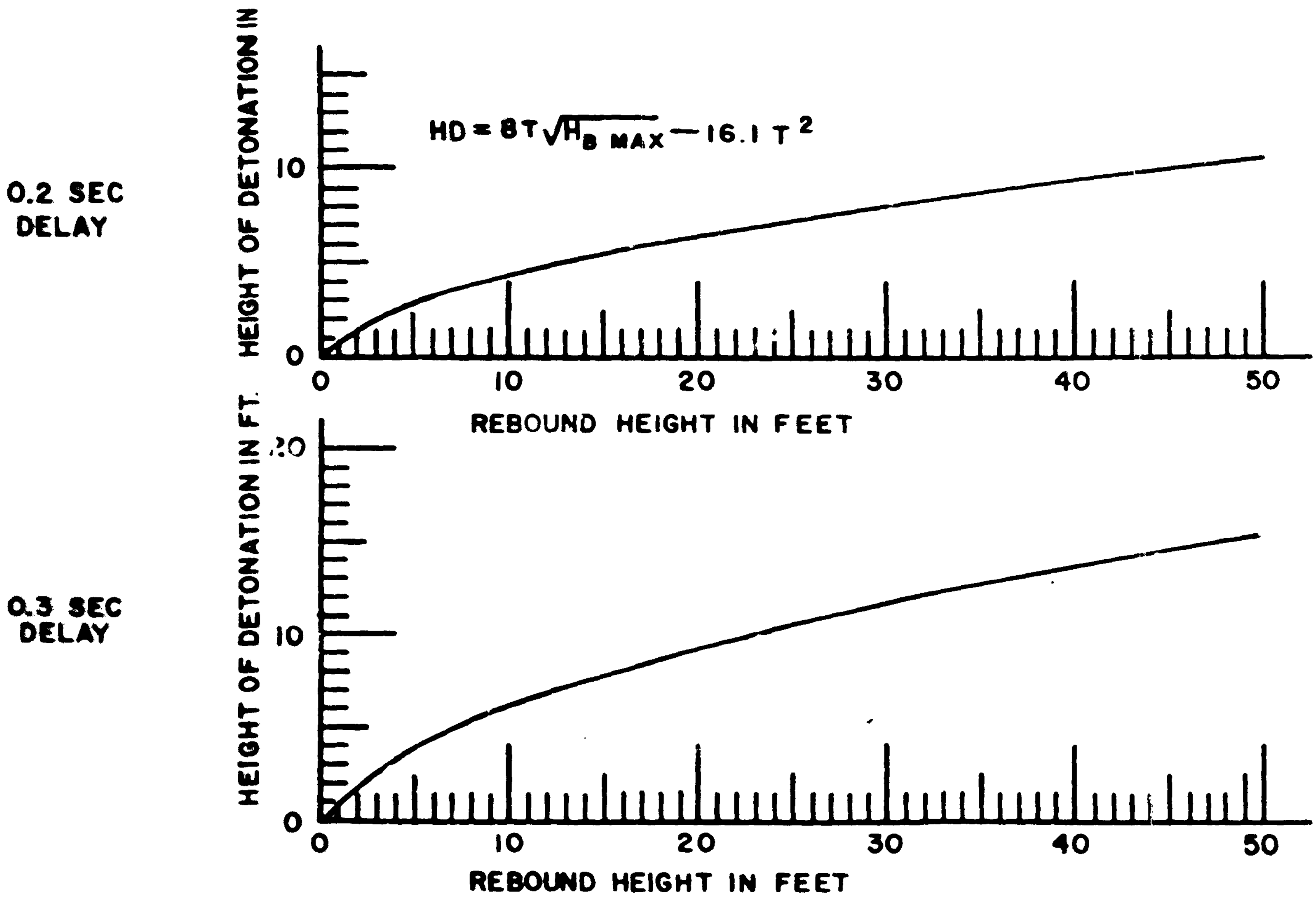

Figure 6. Height of detonation as a function of re. und height, T101? ruze.

targets. A longer delay, on low bounces, would permit the grenade to pass its maximum height and possibly not detonate until return to the ground. For conditions where high rebounds are likely to occur, a long delay could also result in detonation above effective casualty limits.

The development mentioned in the preceding paragraph neglects drag on the grenade, as well as non-vertical rebound trajectories. To check the validity of the 0.25-sec interval under actual rebound conditions, later tests will include delay detonator simulators (section 3.2.5). Simulators with 0.15-sec delay, employed in some early tests, appeared too brief in time.

3.2.5 Rotor and Detonator

The spring-loaded rotor contains the delay detonator. Original rotors were assembled in a recess in the blast cup below the cartridge well. This was superseded by the rotor subassembly illustrated in figures 5 and 7, which includes spring and stop. The rotor is wound and held in the one-piece tool shown, separate from the fuze. To load, the detonator is inserted and the wound rotor unit placed in the recess. The rotor is blocked in this safe position by the locking pin integral with the striker sleeve, the detonator facing 135° away from the tetryl booster at the base of the fuze. Upon arming (section 3.2.1), the rotor steps off the striker sleeve and by the force of its spring rotates to face the booster. Upon target impact, the powder flash from the blank cartridge initiates the delay detonator, which is followed by detonation in the air of the main fragmentation charge.

In conjunction with the T1019 fuze, a short-delay detonator is under development at DOFL. Characteristics required for fuze operation are flash ignition and 0.25-sec delay. No existing small detonator possesses these characteristics. In preference to using a separate delay pellet, the substitution of flash-sensitive, gasless, delay material for the igniting or priming mix in a standard detonator, with minimum change in intermediate and base charges, would produce a small, single-unit delay detonator. This detonator would simplify fuze components and loading procedure, and require a minimum of development investigation.

In February 1954, simulators based on M47 detonator external dimensions were tested for delay at the Electromechanical Laboratory explosive-testing facilities. The simulators were loaded with 50 mg of Catalyst Research Z-2 gasless delay mixture—21% zirconium, 79% barium chromate. Other similar mixtures appear applicable. Ignition was by M42 primer flash in a firing fixture connected electrically to a Potter counter for time measurement. In the setup used for making the time measurement, the striker completes a circuit through the primer upon contact, starting the counter; and the detonator-output shock wave impinged upon piezoelectric crystal which produced an electrical pulse to stop the counter.

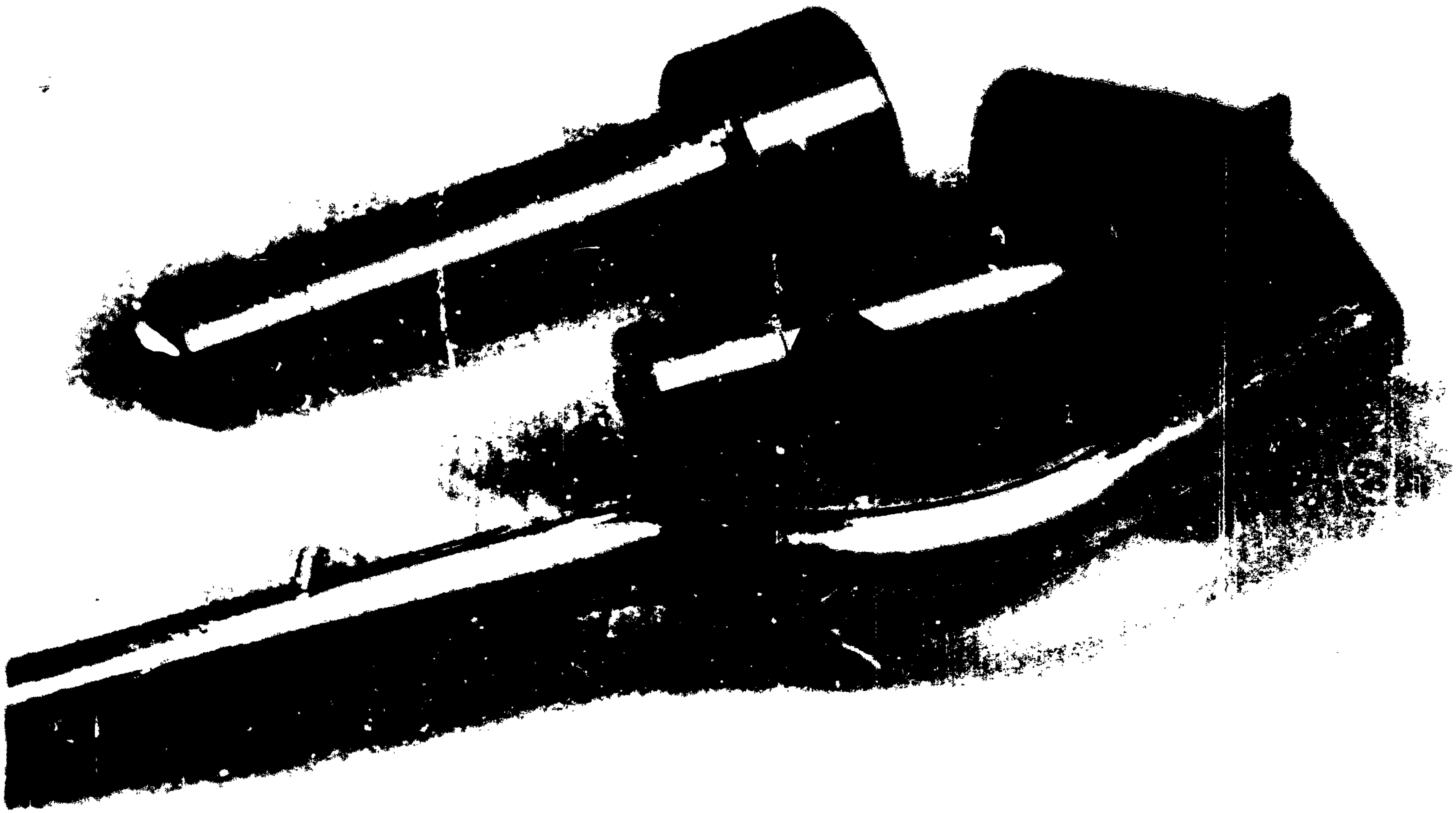

Figure 7. T1019 Fuze models, first design and subassembly revision.

All simulators yielded the required range of 0.2-sec to 0.25-sec delay.

Later detonator samples showed that a 0.25-sec delay could be included in a fully loaded detonator of M47 dimensions (0.145-in. diameter, 0.290-in. long).

The development nomenclature Detonator, Flash, T55 was assigned to this unit by OCO in July 1954.

Tentative loading of the detonator is 50 mg of Z-2 delay mix, 90 mg of lead azide, and 35 mg of PETN. This composite apparently yields the most effective internal performance and output. The cup is thin-drawn aluminum to obviate chemical formation of copper azide as might occur with a gilding metal cup. This design should be small and inexpensive to produce.

3.2.6 Fuze Body

Cold-rolled steel blast cups (fuze bodies) have withstood repeated cartridge firing without failure. Machined 6061ST-6 aluminum alloy mock-ups of T1019 fuze body dimensions failed. All further cups have been cold-rolled steel.

In the initial layout, figure 3, the body was machined with an included recess for the rotor (section 3.2.5). An open vent to dissipate detonator energy lengthwise into the fuze (detonator safety) cannot be used, as a closed well is required for the rebound cartridge. Subsequent detonator-safety tests suggested the application of cheap sheet-metal parts for both rotor and rotor mount.

Electric detonators of comparable output were substituted in these brief tests in the interest of simplicity and handling safety. Metal parts showed damage, and the upper faces of bare tetryl boosters were mechanically crumbled. No tetryl was initiated. Assemblies with sheet-metal rotor housings, affording additional venting volume, appeared superior to machined samples.

The smaller size of the T55 detonator permitted use of a smaller rotor. This assisted in out-of-line safety, as more volume was available for deflecting and dissipating detonator energy.

The present T1019 body pieces were designed from results of the preliminary tests previously mentioned, and also for applicability to rapid production methods such as drawing or stamping. The blast cup is drawn from sheet, or turned round. At the base is spot-welded the thin, sheet-steel crimp plate, supporting the eyelet-type clip rotor. A drawn, sheet-steel cup incloses the rotor, affording out-of-line safety.

The tetryl booster is contained in a thin, drawn-aluminum cup which is roll-crimped to seal the complete rotor assembly.

Parts are on order from commercial sheet-metal fabricators. These will be employed in T1019 assembly-functioning tests and further explosive-train tests.

The present T1019 assembly is shown in figure 8.

4. FUTURE PLANS

A T1019/T48 fuze and grenade combination composed of parts intended for rapid-production methods has been designed as a result of previous developmental work. It is expected that this assembly or a modification of it will be suitable for submission as the first model T48 grenade with T1019 fuze. Considerable testing is required to determine actual assembly performance and improve weak points.

A series of complete-assembly functioning tests is planned for early 1955.

The present fragmentation package (M26 grenade) is probably not the optimum design for this use. Later fragmentation studies will be conducted to evaluate lethal effectiveness.

5. BIBLIOGRAPHY

None.

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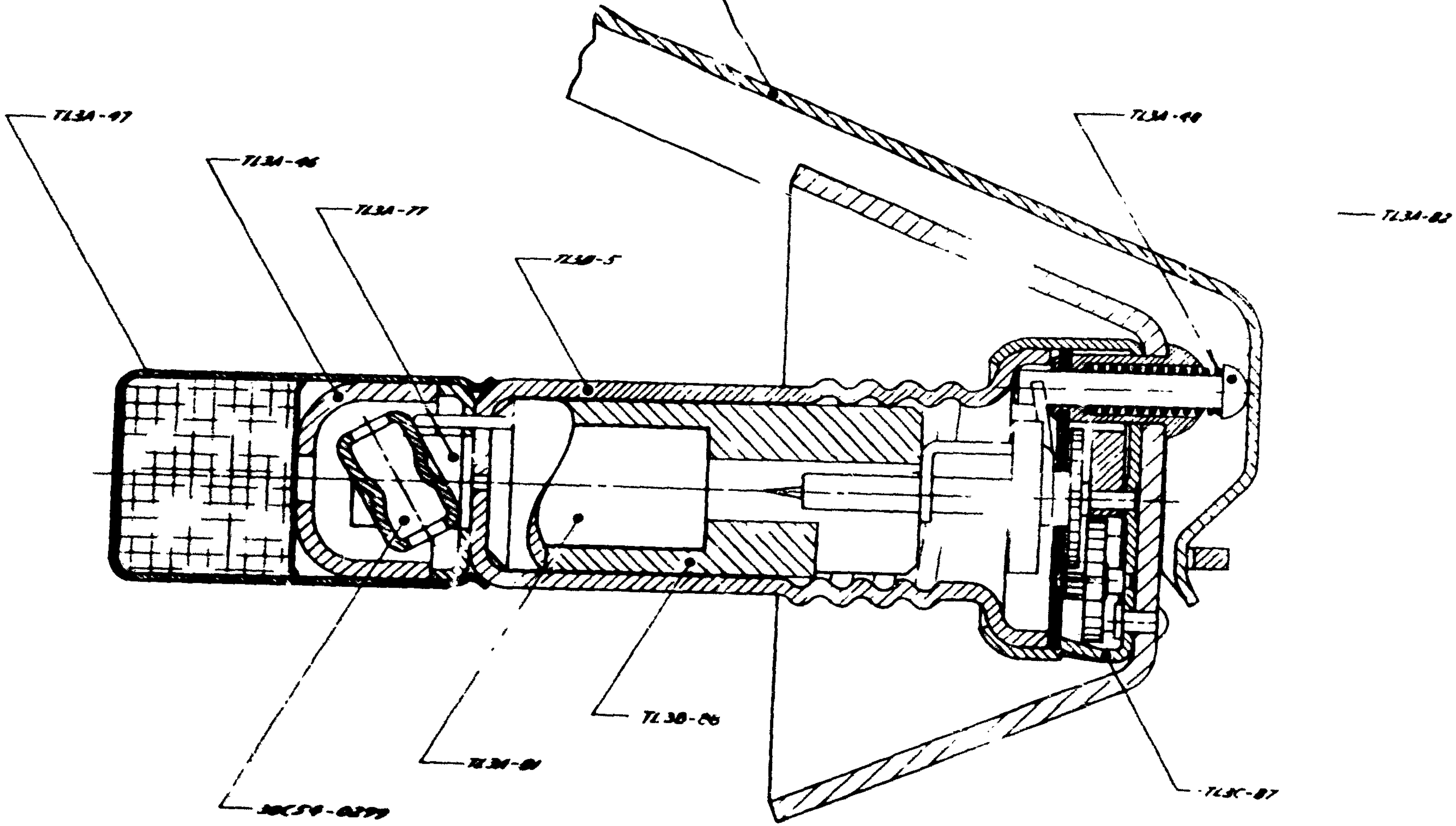

Figure 8. T1019 Present Assembly.